# Forestry Research West

Forest Service
U.S. Department of Agriculture

November 1980



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A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture

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## In This Issue



## Cover

Research Entomologist George Ferrell of the Pacific Southwest Station has developed a system for estimating the longevity of California red fir, Shasta red fir, and white fir. Read about it on page 12. (Photo by Dennis Galloway)

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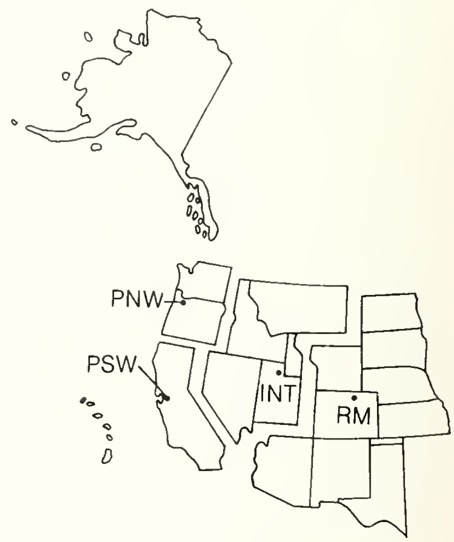


# Managing big sagebrush lands - what's best?

by Rick Fletcher
Rocky Mountain Station

The sagebrush ecosystem is one of the largest rangeland ecosystems in the western United States. Of the several species, big sagebrush (*Artemisia tridentata*) is the most widespread, covering approximately 145 million acres.

Such an abundant species has important environmental and economic implications. Sagebrush lands provide habitat for a variety of wildlife; are an important grazing resource for the livestock industry; are irrigated for agricultural crops, are strip-mined for coal, uranium, and other minerals; are used for fishing, hunting, and other recreational activities; and provide runoff water for local ranchers to help fill tanks and watering ponds for livestock, and even as a municipal water source.

Despite the multiple values, sagebrush management concepts have often been geared toward removal of the shrubs in favor of grasses and forbs for livestock grazing. While this practice increases usable forage production, it triggers changes in other resources as well.

In 1967, researchers at the Rocky Mountain Station, in cooperation with the Bureau of Land Management, began studies at the 7,000-acre Stratton Sagebrush Hydrology Study Area in south-central Wyoming to determine how various sagebrush management practices affect the hydrology of sagebrush lands, their grazing value, and the impact on other resources. Dave Sturges, research forester at the Station's Forest, Range, and Watershed Laboratory at Laramie, Wyoming, says, "These other ecologic and hydrologic changes have received little attention compared to the well-documented response in usable forage production. But, they are changes that need serious consideration before a sagebrush management program is defined."

## Hydrologic relations

"Sagebrush lands are not noted water producers," Sturges explains, "but there is speculation that decreased evapotranspiration subsequent to sagebrush control can increase streamflow since less water from melting snow is needed to rewet soil." Plot studies were initiated at Stratton in 1968 to isolate various hydrologic responses to sagebrush control and thus provide insights into how an entire watershed might respond. Root and

*The volume of soil utilized by individual big sagebrush plants as a moisture reservoir was identified in a study that used a neutron probe to measure soil water content.*

water-use characteristics of **individual** big sagebrush plants were investigated in addition to learning how spraying **stands** of sagebrush with 2,4-D affects snow accumulation and melt, soil water use, and vegetation production. Scientists have found 2,4-D, registered with the Environmental Protection Agency, to be one of the most effective and efficient means of controlling sagebrush. Millions of acres of sagebrush lands have been sprayed in the west over the last 25 years.

## Soil moisture

Seven plots were sprayed with 2,4-D in 1970 killing over 95 percent of the plants; study records now extend over a 10-year period. Soil water depletion was reduced 22 percent the first 8 days after spraying and by fall the soil water recharge requirement was 31 percent less compared to unsprayed plots. The size of treatment effect declined the first 5 years after spraying, but then stabilized in the fifth to tenth years at about a 10 percent difference. All of the reduction in soil water use was located in soil 3 to 6 feet deep beginning the second year after spraying. Thus, Sturges indicates sagebrush control on lands with soils less than 3 feet deep merely shifts the moisture draft from sagebrush to replacement grass species and treatment will have no effect on water yield. On sites with soils deeper than 3 feet which are fully charged each spring, controlling sagebrush does have a potential for slightly increasing water yield.

## Snow accumulation and melt

Records indicate spraying slowed the rate of snow accumulation on treated plots during the early part of the winter even though sagebrush skeletons remained intact. Once snow depth reached the height of the sagebrush stand, about 45 cm, vegetation exerted less and less influence on accumulation. By spring, all vegetation was covered by snow and snow depths on treated and untreated plots were similar to those before spraying. "What we learned," said Sturges, "is that sagebrush control can reduce the rate of snow accumulation if replacement vegetation is shorter than the brush, but once snow covers vegetation, the interaction between topography and wind then controls snow buildup."

Researchers also looked at post-treatment snowmelt characteristics and could detect no difference in the rate of melt on sprayed and unsprayed plots. That is, any difference in snow depth at maximum accumulation on sprayed and unsprayed plots persisted throughout the melt season.

## Vegetation response

A typical response by vegetation to sagebrush control was observed. One year after spraying, researchers found that grass production had doubled and it was 2.6 times that of untreated plots 3 years after spraying. However, total above-ground biomass growth was less on sprayed plots. The increase in grass production did not compensate for lost biomass growth by sagebrush and forbs. Above-ground biomass production on sprayed plots was 29 percent less than on untreated plots the year after treatment, and was still 23 percent less in the third posttreatment year.

## Stream contamination by 2,4-D

The herbicide 2,4-D is usually applied to sagebrush as an aerial spray, and therefore, is subject to wind drift. This can result in contamination of surface waters with possible adverse effects on fish and other aquatic organisms if concentrations reach 1,000 ppb (parts per billion).

A watershed 587 acres in size was sprayed at the Stratton site in 1976 observing standard Bureau of Land Management spraying guidelines. The maximum level of 2,4-D in water samples taken from the creek was 5 ppb which occurred immediately after spraying. Herbicide levels decreased to 3 ppb, between 3 and 12 hours after treatment, and 2 ppb were detected 1, 2, and 3 days after spraying.

Sturges explains, "The primary reason 2,4-D concentrations were so low was because a 100-foot wide unsprayed buffer zone was left on each side of the stream. In addition snow still covered the stream channel which further reduced herbicide entry. We believe spraying guidelines established by the Forest Service or Bureau of Land Management will keep contamination of water to a minimum and thus spraying presents no danger to aquatic organisms."

## Wildlife studies

The U.S. Fish and Wildlife Service's Denver Wildlife Research Center has recently completed studies at Stratton on the effects of sagebrush control on several wildlife species. As yet, results from those studies are not available. However, intensive investigations on how the Brewer's sparrow, one of the most abundant non-game birds occurring in the big sagebrush ecosystem, responds to spraying have been conducted.

Brewer's nests were first located and then sagebrush around half of the nests was sprayed with 2,4-D to indicate how the birds are affected the year of treatment. Production of eggs and young were similar for both treatments. The dried leaves that remained on sprayed sagebrush plants apparently provided sufficient shade and protection from predators.

A different picture emerged, however, when Brewer's use of sprayed vegetation for nesting habitat was compared with use in undisturbed vegetation. Bird densities in an area sprayed with 2,4-D the preceding year was 67 percent lower than in untreated sagebrush vegetation, and 99 percent lower 2 years after treatment. The few birds seen in the sprayed area were near small areas of live sagebrush that had survived treatment.

## A continuing effort

Scientists have learned a lot at Stratton, but their work in evaluating changes that result from sagebrush control is far from over. Currently, John Schmid, entomologist at the Station's headquarters in Fort Collins, is analyzing insects collected on treated and untreated watersheds to determine what species inhabit these ecosystems.

Max Schroeder of the U.S. Fish and Wildlife Service is also compiling data from studies on nesting birds and small mammals. Results from his work should shed light on what effects spraying with 2,4-D have on these animals.

In addition, researchers at the Laramie lab are continuing to assess changes that occur in water yield characteristics such as total annual yield, snowmelt and ground-water runoff, changes in sediment transport, snow accumulation, and soil water use. Traditional range management information about vegetative production and composition, and changes in ground cover are also being evaluated.

For more information on hydrologic aspects of the Stratton study, contact Dave Sturges, Forest, Range, and Watershed Laboratory, 222 South 22nd Street, Laramie, Wyoming 82070. Phone (307) 742-6621, FTS operator 328-1110.

Suggested reading includes the following, all available from the Rocky Mountain Station:

Hydrologic Relations of Sagebrush Lands, a reprint from the Proceedings of the Sagebrush Ecosystem Symposium held in Logan, Utah, April 27-28, 1978, by David L. Sturges.

Soil Moisture Response to Spraying Big Sagebrush: A Seven-Year Study and Literature Interpretation, Research Paper RM-188, by David L. Sturges.

Snow Accumulation and Melt in Sprayed and Undisturbed Big Sagebrush Vegetation, Research Note RM-348, by David L. Sturges.

The Effect on the Brewer's Sparrow of Spraying Big Sagebrush, a reprint from the Journal of Range Management, Volume 28, Number 4, by Max H. Schroeder and David L. Sturges.

*Sagebrush bordering the stream channel was left untreated for wildlife habitat and to reduce entry of 2,4-D into the waterway. Snow still covered the stream channel at the time of spraying which further reduced herbicide entry into the stream.*

# Silver Creek - field laboratory in the Idaho Batholith

by Delpha Noble
Intermountain Station

The Silver Creek Experimental Area within the Boise National Forest is a thriving field laboratory located in one of the most difficult places in the West to harvest timber—the Idaho Batholith.

But timber is being harvested—as Forest Service researchers and land managers engage in a joint venture to harvest old-growth timber from Silver Creek's steep slopes. Boise Forest personnel are managing the timber sales for maximum protection of the forest ecosystem as researchers of the Intermountain Station conduct studies to obtain information on the environmental impacts of the logging activities and associated road construction.

Covering about 16,000 square miles in central Idaho, the Idaho Batholith spans large portions of eight National Forests, extending into Montana. About 80 percent of the area is forested—more than 90 sawmills draw timber from Batholith lands. Thousands of sheep and cattle graze in the area every summer, and the lands support many kinds of wildlife. The recreation potential of this area attracts several million visitors each year. About 50 percent of the total water yield for the State of Idaho originates from the Idaho Batholith.

Administrators responsible for managing Batholith lands are faced with a dilemma: on one hand they receive constant pressure from various interest groups to use the valuable resources. On the other hand, they are well aware of the impacts of logging and road construction, and of the consequences that can result from improper land use practices.

Batholiths are characterized by coarse, granitic soil that can slide or wash away when man or nature removes or disturbs the native vegetation that has become adapted to the harsh environment. The Idaho Batholith can be desertlike in summer, arctic in winter. Logging and road construction on slopes can lead to erosion and sedimentation unless logging and transport systems are selected carefully. Other environmental consequences include flood hazards, effects on wildlife and fisheries, regeneration of forest stands, and timber production.

Walter Megahan, project leader and research hydrologist on the staff of the Intermountain Station, has been involved with the Silver Creek Experimental Area since the earliest planning activities. He says, "It has been impossible to accurately predict the onsite and offsite effects of these environmental consequences, posing a crucial problem for the land manager. He is unable to define limitations to use, if and how management practices might be applied, and possible tradeoffs in the various uses and values, even though he is required to do so for environmental analysis reports."

The research being conducted at Silver Creek is designed to provide many of these capabilities. The studies are multi-disciplinary, an approach that is particularly appropriate because of the many interactions that exist. In addition to being able to predict the environmental effects of selected land uses, the research is designed to devise ways to minimize adverse effects on areas where disturbance is unavoidable.

## The study area

The experimental area is located within the Emmett Ranger District of the Boise Forest in the headwaters of the Silver Creek drainage, a tributary of the Middle Fork of the Payette River.

*Recording precipitation at a climatic station on Silver Creek.*

The 2,300-acre site is representative of much of the range conditions found in the Idaho Batholith. Soils range in depth from about 50 inches in the lower portions of the study watersheds to less than 10 inches in the drainage heads. Side slopes also vary greatly—they range from a gentle 10 to 20 percent to nearly vertical 80 percent. Elevations range from 4,500 to 6,700 feet. All drainages flow in a southeast direction except one creek that flows northwest. Ponderosa pine, Douglas-fir, and white fir are the dominant tree species.

Research data collected over the past 15 years provide a storehouse of information unparalleled anywhere in the Idaho Batholith. This, and data from past inventories of soil, timber, vegetation habitat, and hydrologic characteristics, supply baseline knowledge adequate to evaluate the impacts of timber harvesting and road construction activities.

Seventeen different studies are being conducted on eight small watersheds ranging in size from 64 to 500 acres. Major areas of investigation are:

SILVICULTURE — size of cut opening; site preparation; regeneration; timber productivity; residual stand responses.

ENGINEERING — forest road design, construction, and revegetation; harvesting systems and techniques.

WILDLIFE — responses; changes in habitat.

SOILS — nutrients; surface conditions.

HYDROLOGY — streamflow rates; water chemistry; sediment yields; stream channel characteristics.

*Researcher analyzes the chemical content of stream water samples.*

ENTOMOLOGY — aquatic insect activity and habitat.

ECOLOGY — plant succession; biomass.

ESTHETICS — impacts of road construction and timber harvest practices.

## Silvicultural practices

The timber sales at Silver Creek form a logging mosaic on eight small watersheds ranging in size from 64 to 500 acres. Cutting is designed to remove about 35 percent of the total stand on each watershed. In 1976, helicopters were used to remove portions of the timber stands from two of the watersheds. Logs from three of the watersheds will be removed with a skyline—similar to a short ski tow powered by a crane. All merchantable trees in units up to 25 acres will be clearcut on two of the watersheds. Two other drainages will be clearcut in units up to 5 acres. Another will be clearcut in units up to 1 acre, and two of the watersheds will be cut by selection. One watershed will be left undisturbed as a basis to compare and evaluate the effects of silvicultural practices on the others. The study results will tell researchers which method and what intensity of logging produces the least ill effects.

## Road construction

Previous research on steep, granitic slopes has shown that roading has great potential for accelerating erosion. Megahan says, "We know that erosion hazards can be reduced considerably by modifying road design and construction practices." He adds that additional research is needed, however, to measure the cost versus erosion reduction relationships for these practices. Another serious question with respect to road erosion is, "How much and when do eroded materials reach downstream locations, and what are the biological impacts as the sediments move through the channel system?" Megahan says, "Although we presently have some knowledge of the effects of roads on sedimentation, we know almost nothing about effects on water chemistry and streamflow rates." The road-related studies at Silver Creek are designed to help answer some of these questions.

Construction of roads on three of the watersheds began this past summer. Road construction is limited to three drainages, using three standards of construction and two levels of erosion control practices.

In each drainage, the roads are 14 feet wide, but there the similarity ends. The surface varies from nothing but dirt to gravel and a gravel-asphalt mix. A variety of road design practices are being used in the construction. Field instruments will record data telling researchers which combination produces the least erosion.

The roads will be allowed to sit for at least 3 years before logging begins. That will allow researchers to measure the impact of the construction without mixing the sediment from logging in with the results.

Researchers are confident that there are many valuable uses of the knowledge being gained from the Silver Creek studies. Much of the information can be directly applied on granitic soils of the Idaho Batholith and on other batholiths of the western United States. Land managers can use the information to evaluate possible effects of planned activities on water quality, streamflow, and aquatic systems. The information will also allow them to develop and evaluate alternatives and timing strategies. Engineers will be able to predict impacts that will result from planned road locations and designs. And as they consider tested design techniques and treatments, they will have cost-effective information on which to evaluate alternative choices.

Researchers will have further insight into the basic erosion processes occurring on disturbed soils, and will be able to provide basic data for developing and using watershed response models.

## Transferring the technology

Technology transfer, which has been defined as a "continuous process with live circuits," is an integral part of the Silver Creek program. As various studies are completed, the results are published for immediate application by land managers. Other applications of results occur through presentations at meetings of forest engineers, hydrologists, and soil scientists; during field training sessions; and presentations to professional organizations.

Publications relating to the Silver Creek studies, now available from the Intermountain Station, include:


Clayton, James L., "Nutrient gains to adjacent ecosystems during a forest fire: an evaluation," For. Sci. 22(2), INT-R-455.

Clayton, James L., "Soil disturbance following clearcutting and helicopter yarding in the Idaho Batholith," (available after January 1, 1981).

Clayton, James L., and C. E. Jensen, "Water retention of granitic soils in the Idaho Batholith," INT-RP-143.

Clayton, James L., and Debora A. Kennedy, "A comparison of the nutrient content of Rocky Mountain Douglas-fir and ponderosa pine trees," INT-RN-281.

Fausset, Neal E., James K. Applegate, Paul R. Donaldson, and Lane D. Eggers, "Geophysical investigation of rock properties near Silver Creek, Boise National Forest, Idaho," **In** Proceedings of the 16th Annual Engineering Geology and Soils Engineering Symposium, Boise, Idaho, April 5-7, 1979. p. 201-218.

Hart, Donald S., and Merlyn A. Brusven, "Comparison of benthic insect communities in six small Idaho Batholith streams," Melanderia, Vol. 23, 1976.

Megahan, Walter F., "Channel sediment storage behind obstruction in forested watersheds draining the granitic bedrock of the Idaho Batholith," **In** Proceedings of the workshop on sediment budgets and sediment routing, Corvallis, Oreg., May 30 - June 2, 1979.

Megahan, Walter F., "Volume weight of reservoir sediment in forested areas," J. Hydraul. Div., ASCE, Vol. 98, INT-R-252.

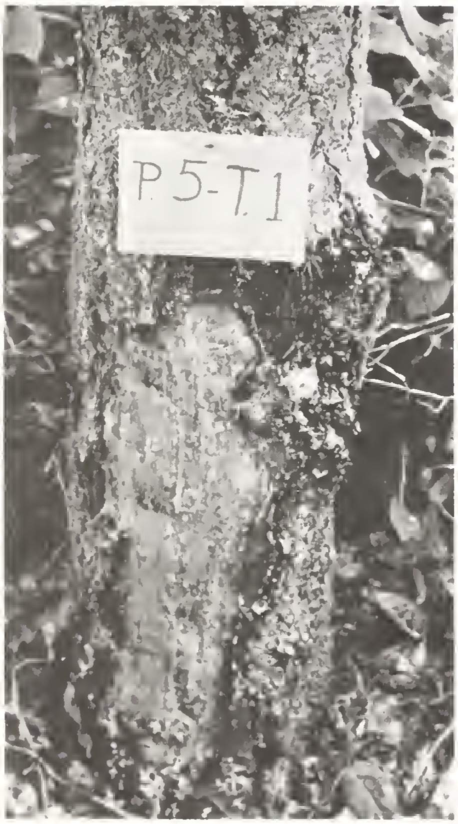
Megahan, Walter F., and Roy A. Nowlin, "Sediment storage in channels draining small forested watersheds in the mountains of central Idaho," 3rd Fed. Interagency Sedimentation Conf. Proc., 1976, INT-R-438.


*Servicing a water level recorder at a stream gage.*

# Logging injuries increase decay in true fir

by Dorothy Bergstrom
Pacific Northwest Station

Basal wounds, like this one, are more serious than other wounds because moisture from the ground hastens fungal entry.




If intensive management of second-growth true fir is to produce more timber on a reduced land base as foresters anticipate, logging wounds must be reduced. Wounds to trees that occur during repeated stand entries are often infected by decay fungi, resulting in unnecessary loss of wood. Losses as high as 14 percent of the board-foot volume were measured in one study in northern California.

This is the urgent message from Paul Aho, forest pathologist with the Pacific Northwest Station's Forestry Sciences Laboratory in Corvallis, Oregon. His assessment is based on recent studies of decay in young, managed stands of true firs in Oregon, Washington, and California.

"We used to think that when the highly defective old-growth true fir was cut, losses from decay would drop drastically because the younger managed stands would be healthier and rotations shorter," says Aho. "Although losses to decay in advance regeneration are less than in old growth, they are much greater than anticipated and incompatible with goals to increase wood production," he said.

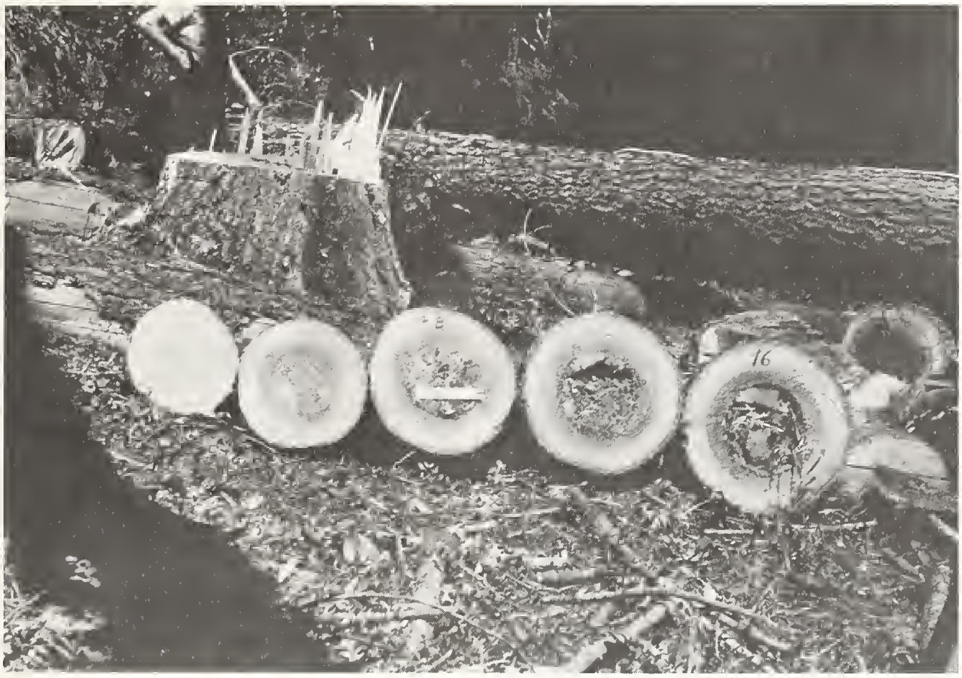
Aho began his studies because forest managers in eastern Oregon and Washington had become concerned about future yields from second-growth fir stands. The large amount of decay present in old-growth true fir raised questions about how much decay might already be present in the second-growth stands that were expected to provide the next timber crop. As a result of past management practices, including fire control, advance true fir regeneration now covers thousands of acres formerly dominated by pine stands. Although these young stands have been suppressed for decades, they grow fast when released and appear ideal for future intensive management.

In his studies, Aho had the benefit of discoveries made in 1975 by Canadian forest pathologists about the Indian paint fungus (*Echinodontium tinctorium*)—one of four species that cause most decay in true fir and hemlock. The scientists found that this fungus can invade wounds as small as a pinhead—or where a shade-killed twig breaks off. It had been assumed previously that only large dead branches and stubs were infected. The scientists also discovered that the fungus invades suppressed trees that are unable to grow new wood fast enough to close the small wounds. Once in the bole of the tree, the fungus can remain semidormant for decades, then become active when another wound occurs near the infection site.

Aho already knew that Indian paint fungus was causing almost 80 percent of the decay in old-growth grand and white fir in eastern Oregon and Washington. Now he became concerned about the ability of the fungus to invade suppressed regeneration. He suspected that if trees already infected by the fungus were wounded later during selection cutting, the result might be substantial decay at rotation age and reduced wood production.

## Logging damage studied

To learn more about the extent of the problem, Paul Aho and Greg Filip, a forest pathologist with the Forest Service's Pacific Northwest Region, began a study in the Fremont National Forest in southern Oregon, in 1977. They surveyed four stands of advance white fir regeneration. One stand still had an overstory of mature white fir and ponderosa pine. The overstory had been removed from the other three stands.



*These cross sections from an old-growth white fir tree show extensive decay caused by Indian paint fungus.*

More than 50 percent of the trees sampled had at least one wound. Decay was negligible because the wounds were so young. But laboratory studies later indicated that 22 percent of the trees were infected by the Indian paint fungus. Most of the infections were dormant. The three other important decay fungi—*Pholiota* sp., *Hericium abietis*, and *Fomes annosus*—were also present.

Because of these findings, Aho and Filip began a more extensive study in 10 National Forests in eastern Oregon and Washington. They sampled 20 trees in each of 25 stands of suppressed grand and white fir that had been precommercially thinned after removal of the overstory. More than half the trees had one or more injuries, and 53 percent of the wounds had associated decay. The amount of decay was small—2.5 percent of the cubic volume and 4.0 percent of the board-foot volume. But since the trees were small, averaging only 5.9 inches in diameter and 31 feet in height, and would take decades to reach merchantable size, decay could be expected to increase significantly by harvest time.

Indian paint fungus was found in almost a quarter of the trees sampled. Slightly more than half the infections were already causing decay. Of the infections that were still dormant and had not begun to cause decay, 70 percent were in trees that had not been wounded.

In 1979, another study of logging damage was begun at the request of managers in the Lassen National Forest in northern California. The managers were concerned about possible decay losses from injuries caused during commercial thinning of white and red fir. Cooperating with Aho in the study were two scientists with the Forest Service's Pacific Southwest Region: Mike Srago, a forest pathologist with Forest Insect and Disease Management, and Gary Fiddler, a silviculturist at the Silvicultural Development Unit at Burney, California. They felled and dissected 225 wounded true firs from 11 stands that had been thinned 4 to 25 years earlier. They found 275 wounds averaging 13 years in age; all were infected by decay fungi. The decay had caused a loss of 4.5 percent of the merchantable cubic volume and 14 percent of the board-foot volume. The fungi causing the decay were the wound invaders *Pholiota* sp., *Hericium abietis*, and *Fomes annosus*. The Indian paint fungus was found only in limited areas and did not account for much decay.

"These losses are serious," says Aho, "because decay will increase substantially during the 40 to 60 years before trees grow to harvest size."

To find out whether more careful logging reduces injury to crop trees, Fiddler and others at the Silvicultural Unit surveyed the damage to white and red fir stands in northern California. These stands, less than 100 years old, had been commercially thinned. In some stands, conventional logging methods were used; in others, techniques designed to reduce injury were used. In stands logged by conventional methods, wounds were found on 22 to 50 percent of the crop trees; three-quarters of the wounds were in contact with the ground. In three stands, 8 to 18 percent of the crop trees were so badly damaged they were not worth growing to harvest age. In stands thinned by methods designed to reduce injuries, however, only 5 to 14 percent of the crop trees were wounded and none were worthless.

## Ways to reduce injury

Aho strongly recommends that forest managers follow the practices that sharply reduced tree injury in the California study:

Presale Preparation

1. Timing is important. Do not log during the spring and early summer when the sap is flowing and the bark is loose. Trees are more easily wounded then, and injuries tend to be larger.

2. Select the size and type of logging equipment appropriate to the topography, tree size, soil type, and soil conditions. For example, cable yarding systems should be used on slopes steeper than 35 percent. On more gentle terrain, use track-laying or rubber-tired skidding vehicles. Equipment should be no larger than needed for the size of logs to be removed. On clay soils, or soils saturated with moisture, use skidding equipment that produces low pressure to reduce soil compaction. In stands that will tolerate little damage, consider using horses to skid logs.

3. Mark leave trees, instead of those to be cut. This calls attention to the crop trees; as a result loggers are more likely to avoid hitting them.

4. Lay out skid trails in advance. They should be only slightly wider than the skidding vehicle and preferably no wider than 8 feet. Trails should follow straight lines to minimize skidding distances, and there should be no sharp turns. Some trees along the edges of skid trails can be designated "bump trees" and removed last.

5. Cut logs short enough to minimize scarring of the residual stand.

6. Do not thin stands of young, thin-barked species, such as hemlock, too heavily. The leave trees may suffer from release shock or sunscald wounds. These wounds nearly always become infected, and associated decay is usually extensive.

### Logging techniques

1. The first step in logging is to cut and remove trees in skid trails so fallers can locate the trails easily. Cut stumps low—as low as 3 inches above the ground—to prevent the skidder from being shunted sideways and bumping residual trees.

2. Fell trees either toward or away from skid trails. This will reduce maneuvering of the skidder that is likely to result in damage to leave trees.

3. Use end-line skidding; that is, skidders should remain on skid trails and the cable pulled out to the logs.

4. Before skidding, trees should be limbed flush to the bole, topped, and cut into logs.

"If these procedures are followed," says Aho, "logging damage will be minimal, decay will be reduced, and the residual stand will be capable of responding to thinning."

*This large sunscald wound was caused by too heavy thinning in white fir.*

## Factors affecting decay

Whether decay results from wounding depends on the size of wounds, the time they take to heal, their location on the tree, and the species of tree wounded. The likelihood of decay increases with the number of wounds to the same tree.

If a wound is large, it is more readily infected and decay is more likely. Deep, gouged wounds are more frequently infected and likely to have more decay. Also, if the surface of a wound is rough, it takes longer for new wood to grow over it, leaving more time for decay fungi to enter.

Wounds in contact with the ground nearly always become infected, and decay progresses faster than in wounds above the ground line. Basal wounds also mean greater losses of timber, since much of the value of a tree is in the butt log.

Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and pines. Sitka spruce is an exception; it has resin ducts but is also very susceptible to invasion by fungi when wounded.

Environmental conditions—rainfall, aspect of slope, topographic position, elevation, and site—probably influence the amount of infection, but Aho says information on these factors is scant and often contradictory.

Frost cracks, shake, and wet wood are other complications often associated with wounds in true fir and hemlock. In old-growth forests, these defects were mainly initiated by fire wounds and caused significant losses of volume. In second-growth forests, logging wounds are replacing fire as the major cause of these defects.

## Outlook for the future

What is the outlook for second-growth true fir forests? Can the growth expected with intensive management make up for the current losses to decay? No one knows for sure, but Aho feels the prognosis is not good unless wounding of residual trees is reduced. He is convinced that the logical, cost-effective way to do this is to adopt logging practices designed to protect crop trees during entries to stands.

"Once an injury is made," Aho says, "there are no chemical or biological methods for protecting trees from decay fungi. The best control is prevention—by using improved, easily adapted logging techniques."

## Additional information

Aho has written about his findings in "Decay of Grand Fir in the Blue Mountains of Oregon and Washington," Research Paper PNW-229, available from the Pacific Northwest Station, and in "Incidence of Wounding and Associated Stain and Decay in Advanced White Fir Regeneration on the Fremont National Forest, Oregon" by Gregory M. Filip and Paul Aho, available from State and Private Forestry, Pacific Northwest Region, USDA Forest Service, P. O. Box 3623, Portland, Oregon 97208.


*This cross section of white fir shows decay associated with a wound.*

As a basic text on the process of decay, Aho recommends a publication based on the research of Alex Shigo at the Northeastern Station. "Compartmentalization of Decay in Trees," by Alex L. Shigo and Harold G. Marx, Agriculture Information Bulletin No. 405, is available from the Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402, (Stock No. 001-000-03671-8; price $1.85).

# Risk-rating systems developed for firs

by Marcia Wood
Pacific Southwest Station

A new technique for "risk-rating" fir trees in northern California has been developed by Research Entomologist George Ferrell of the Pacific Southwest Station. Ferrell's risk-rating systems are based on easily assessed characteristics of mature California red fir, Shasta red fir, and white fir. The systems present a rapid and reliable method for determining the probability that a given fir will die within the next 5 years. Although this information can be used in a variety of ways, Ferrell expects that one of the most common uses will be in deciding which trees might be best to remove from stands. A silviculturist, for example, could determine that mature red firs with a 70 percent or higher probability of dying within the next 5 years should be cut at the earliest planned harvest; firs with lower risk ratings could be left in the stand until later.

Crown raggedness made a difference in the risk-ratings of the two mature red firs (adjacent each other) here. The tree at left has only 5 percent risk of death; the one at right has a risk-rating of 19 percent.

The systems—one for white fir and one for both California red fir and Shasta red fir—are based on two summers of field observations of characteristics of several thousand living or recently killed firs. The systems are easy to use and statistically sound. They are best applied to northern California sites similar to those at which they were developed. This area of applicability includes the Sierra Nevada north of Lake Tahoe, the southern Cascades, the eastern Siskiyou Mountains, the Salmon-Trinity Mountains, the Warner Mountains and nearby ranges, and the Marble Mountains. About 40 percent of the commercial red fir and white fir forest land in California is in this region.

The systems are designed to give managers of fir stands the same kind of aid that the Ponderosa Pine Risk Rating System, developed in the 1930's, has provided managers of ponderosa pine and Jeffrey pine stands. The Pine System, developed by K.A. Salman and J.W. Bongberg, along with the tree classification systems developed by F.P. Keen and Duncan Dunning, all of the Pacific Southwest Station, started Ferrell on the fir rating systems. "The earlier work with pines suggested that a system for risk rating firs would be feasible and practical to develop," Ferrell says. The need for a fir system was obvious—for lack of information on how to assess risk in firs, many foresters were using the pine systems to get some idea of how to evaluate questionable-looking firs.

Much support for the risk-rating project came from the National Forest System's Pacific Southwest (California and Hawaii) Region. Regional Silviculturist John Tappeiner says, "In many cases, we could pick out the better firs from the poorer ones. But, we had no way of estimating how long the poorer ones would live. The systems give us a way to make these estimates."

## Rating a tree

The systems focus on easily distinguished features of mature firs that are at least 10 inches in diameter and are growing either in virgin old-growth stands or old-growth stands that have been cut over but still have some mature overstory. In each system, four tree characteristics are evaluated. A tree that is being risk-rated is given "award" points for positive characteristics and "penalty" points for negative features. Total points are computed and matched to a percent rating, to indicate the probability that the rated tree will die sometime within the next 5 years. The system is described in detail in General Technical Report PSW-39, "Risk-Rating Systems for Mature Red Fir and White Fir in Northern California." This Report is available from the Pacific Southwest Station.

For California red fir and Shasta red fir, award points are given for crown class; possible scores range from 6 points for a dominant tree to no points for a suppressed tree. Points are also awarded for the percentage of the tree's height that is made up of living crown—5 points for each 10 percent of the tree height that is living foliage. Penalty points are given for a recent topkill, and for the percentage of the total crown that looks ragged. A ragged crown could be one that is missing branches along one side, or has dead or dying branches here and there.

*Award-Penalty Risk System for mature red fir*

| Crown Class | Award |
|---|---|
| Suppressed . . . . . . . . | 0 |
| Intermediate . . . . . . . . | 2 |
| Codominant . . . . . . . . | 4 |
| Dominant . . . . . . . . | 6 |
| Live Crown Percent (to nearest 10 percent of tree height) | |
| 5 points for each 10 percent . . . . . . . . | ____ |
| Total Award . . . . . . . . | ____ |
| **Top Condition** | **Penalty** |
| Recent topkill . . . . . . . . | 1 |
| Ragged Percent (of crown missing, dead, and dying to nearest 10 percent) | |
| 4 points for each 10 percent . . . . . . . . | ____ |
| Total Penalty . . . . . . . . | ____ |

Risk Point Total

a. Enter Total Award or Penalty (whichever larger) . . . . . . . . ____

b. Subtract smaller Total . . . . . . . . ____

c. Risk Point Total . . . . . . . . ____

Percent Mortality (within 5 years)

a. Award equals or exceeds Penalty . . . . . . . . . 0 to 20 percent

b. Penalty exceeds Award

| Points | Percent | Points | Percent |
|---|---|---|---|
| 1 to 4 | 21 to 30 | 15 to 17 | 60 to 70 |
| 5 to 8 | 30 to 40 | 18 to 21 | 70 to 80 |
| 9 to 11 | 40 to 50 | 22 to 25 | 80 to 90 |
| 12 to 14 | 50 to 60 | 26+ | 90+ |

*Red fir can be risk-rated with this scorecard.*

The white fir system uses a few different criteria. Healthy trees are given award points for each 10 percent of crown length that is composed of upswept or horizontal branches. White fir penalty points are based on both the crown density (3 penalty points for a thin crown, no penalty for a dense crown) and on the percent of the crown that is ragged. Bark fissures are also used as risk predictors—if living inner bark doesn't show up between the outer bark plates, the tree receives 28 penalty points; if live inner bark is apparent, there's no penalty.

Ferrell says that using these predictors is a straightforward procedure that can, after some practice, be completed in "just a few minutes." He emphasizes, however, that the systems do not determine how a stand should be managed. "The systems give percent probabilities—it's up to the manager to determine what percentages are 'high' or 'low' risk for each stand."

*Although about 60 percent of the crown of this white fir is ragged, the risk-rating system indicates that there is only a 4 percent chance that the tree will die within the next 5 years.*

The four predictors used in each system were the best in the field of 22 different characteristics that Ferrell analyzed and monitored during two summers of data collection. He used a computer program developed by David Hamilton and others at the Intermountain Station to determine which predictors would be the most reliable. Those selected have an accuracy of 95 percent or better. (Characteristics that had a high accuracy rating, but were eliminated to keep the systems simpler, included crown class and diameter class, which were eliminated as predictors for white fir, and crown width and crown density, which were not used for the red firs.) After narrowing the field of candidate characteristics, he used another of Hamilton's computer programs to determine probabilities for each of the selected predictors.

## Applications

The systems should be useful in making many types of stand management decisions. In a sanitation salvage, for example, the systems could be used to identify trees that are the most likely to be lost to destructive insects and diseases. These trees can be removed from the stand (salvaged) before they become both a loss and a center of insect and disease activity. In a shelterwood harvest, the systems could be used to indicate which overstory trees will survive long enough to provide seed and shelter.

Ferrell expects the systems to be helpful not only to people who are just starting out in forestry but also to those who have been in the field for a long time. For newcomers, such as summer or part-time employees who are learning how to mark timber, the systems provide "a common basis for training," Ferrell says, and "allow markers to come to consistent estimates of risk." For those who already have a lot of experience estimating risk, the systems may help refine their judgement. Silviculturist Dick Castaldini of the Plumas National Forest says the systems have sometimes changed his mind about which trees to cut. "I was surprised to find that some of the white firs I normally would have cut were not that badly off, after all," he explains. "In our own marking, we may have taken these trees, but the risk systems indicate we didn't have to."

## Limitations

Prospective users of the systems should be aware of some limitations. Probably the most important is the geographical restriction—the systems can't provide reliable results if they are used outside of the northern California areas for which they are intended. (Ferrell is currently working on a special risk-rating system for the central Sierra Nevada.) A second important limitation is that the systems should not be used as the sole criterion for a stand management decision. As Regional Silviculturist Tappeiner explains, "The risk-rating systems are a guide—they can help people write a stand management prescription. But, if people use just the risk-rating approach without looking at other parts of the stand environment—the microclimate, the stocking level, and other factors—the systems won't work. The systems alone won't help determine what a stand is doing; they have to be used with judgement and care."

A final limitation of the systems is that there may be some northern California sites to which they do not apply. Tappeiner explains, "Firs occur on so many different site conditions that it would have been impossible for George to test the systems on them all."

Although the systems are limited to a 5-year prediction span, this is one limitation that is not now seen as important, by some prospective users, even though most cutting plans involve cutting intervals of at least 10 years. Dean Angelides, forester with Southern Pacific Land Company's Tahoe District, says, "Even though the systems only go up to 5 years, they are better than our best guess, right now. If we look more critically at the characteristics Ferrell calls important, we should be able to make 10-year estimations."

Ferrell himself predicts that the risk-rating systems will have "an important financial impact on forest management in California" and will "affect the harvesting of many thousands of mature, sawtimber-sized trees over the coming years."

# New publications

## A new report on ponderosa pine

Managing the 6.7 million acres of commercial forestland dominated by ponderosa pine in the Pacific Northwest represents the ultimate challenge to the silviculturist, according to researcher Jim Barrett of the Pacific Northwest Station. Ponderosa pine forests can be prime examples of how multiple-use management works. They produce wood for a wide variety of products, abundant grazing for livestock, cover for wildlife, and a variety of recreation opportunities for people.

Barrett has pulled together information that has been accumulating for 60 years about all aspects of managing ponderosa pine, and organized it in a report that should be particularly useful to practicing foresters. A bibliography of more than 100 references is included.

In the report, Barrett discusses reasons for the marked drop in the amount of commercial forestland dominated by the species. Barrett says it is the result of cutting practices and the exclusion of periodic ground fires that once helped maintain the fire-resistant pine stands. As the mature pine overstory has been cut, the land type has shifted to other single species types or the mixed conifer type. Even though this shift has taken place on about 5 million acres in Oregon and Washington in the last 25 years, lumber products valued at $569 million were produced in 1976 from the ponderosa pine forests that remain in the two States.

Barrett also makes recommendations for future research, which he feels should include replicated trials of silvicultural systems in the major habitats of the ponderosa pine type.

Copies of "Silviculture of Ponderosa Pine in the Pacific Northwest: The State of Our Knowledge," General Technical Report PNW-97, by James W. Barrett, are available from the Pacific Northwest Station.

## All about the tussock moth

A major tool for transferring knowledge about the Douglas-fir tussock moth and its place in ecosystems of the Western United States is a report recently completed at the Pacific Northwest Station. The report covers the entire spectrum of knowledge about the insect, from its biology to computer models for simulating behavior in future outbreaks.

Much of the information came from work supported by the USDA Expanded Douglas-fir Tussock Moth Research and Development Program, which was established in 1974 to coordinate and accelerate work on the insect after a severe outbreak in eastern Oregon and Washington in 1971-74. The program was headquartered at the Pacific Northwest Station.

The book was written by 45 scientist authors and was organized and edited by a technical editor and two entomologists. The publication was planned early in the program as an important, final product. While scientists were conducting studies they were also planning how they would report their findings and synthesize them with previous research on the insect, and do this in a form useful to managers.

Copies have been distributed to universities and libraries. Additional copies can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. "The Douglas-fir Tussock moth, A Synthesis," edited by Martha H. Brookes, R. W. Stark, and Robert W. Campbell (Stock No. 001-000-03924-5) sells for $16.75.

## Eucalyptus studied

Two new reports on growth of eucalyptus trees are now available from the Pacific Southwest Station. In one report, Research Forester Jerry Walters of Honolulu, Hawaii, analyzes spacing intervals used in sawtimber plantations of saligna eucalyptus. The plantations were located on the north slope of Mt. Haleakala on the Island of Maui, and were planted at spacings of either 8 by 8 feet, 10 by 10 feet, 12 by 12 feet, or 14 by 14 feet. At periodic intervals during the 15-year study, Walters measured diameter, height, height to a 4-inch and a 9-inch top, and height to live crown; he also calculated board foot and cubic foot volumes.

He found that the total amount of wood produced in 15 years was about 29,000 board feet per acre, regardless of the spacing interval. However, he recommends the 14 by 14 foot spacing as "probably the most economical for a sawtimber operation." He explains that the 14-foot spacing required fewer trees to harvest: 100 trees per acre at the 14-foot spacing produced the same volume as 162 trees per acre at the 8-foot spacing. He says that trees in the 14 by 14 foot spacing should be harvested at 15 years, in order to avoid some of the growth stresses that occur in older eucalyptus.

Details about the study, and Walters' comments on possible spacings for pulpwood plantations and combined pulpwood-sawtimber plantations, are in the report, "Saligna Eucalyptus Growth in a 15-year-old Spacing Study in Hawaii," Research Paper PSW-151.

In the second report, researcher James P. King of the Pacific Southwest Station, Honolulu, and former PSW scientist Stanley L. Krugman, now with the Forest Service's Washington, D.C., office, describe a northern California test of 36 different species of eucalyptus. The purpose of the test was to determine which species would grow well at low-elevation sites in central California.

The species used in the study were recommended by Australian scientists, and were selected from among 500 species of eucalyptus on the basis of their cold-hardiness, good form, and potential usefulness for landscaping or for providing wood products or wildlife habitat.

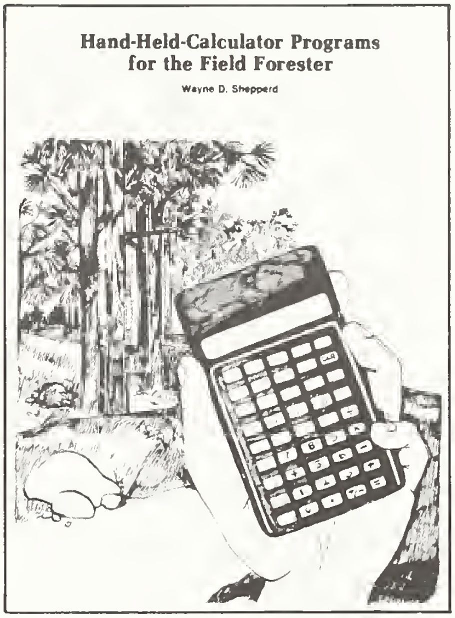
For the test, small stands of each species were planted on a test site about 20 miles northeast of San Francisco. The study area was similar to inland areas where the best-performing eucalyptus might be used in future plantings. On the basis of observations made over a period of about 12 years, King and Krugman recommend only seven species for further testing. These are: red-gum eucalyptus (*Eucalyptus camaldulensis*), mountain-gum (*E. dalrympleana*), tingiringi-gum (*E. glaucescens*), rose-gum (*E. grandis*), shining-gum (*E. nitens*), swamp-gum (*E. ovata*), and manna eucalyptus (*E. viminalis*). These species had "high survival, made good growth, and readily recovered from a record-breaking freeze that occurred during the study." Further recommendations about planting eucalyptus in California are in the report, "Tests of 36 Eucalyptus Species in Northern California," Research Paper PSW-152.

# Calculator help for field foresters

The popularity of hand-held programmable calculators for field use is increasing. They are small, inexpensive, easy to use, and rugged enough for outdoor use. Some models can store and execute programs containing over 2,000 steps.

A new report is now available that describes various programs designed to help foresters use hand-held, programmable calculators to gather and analyze data in field situations. Programs are presented which perform: slope to horizontal distance conversions; basal area computation; tree height determinations; adequacy of sample test; multispecies board foot volumes; basal area factor gauge calibration; limiting distance; scaling of aerial photos; calculations for variable plot cruising; and variable plot cruising summaries.

Programs described are written in outline form and are not specific to any particular brand of calculator. However, a calculator with 200 or more program steps is desirable. The programs are presented in order of complexity, so the user is gradually introduced to the more advanced programming techniques.




The Rocky Mountain Station has copies of this report. Request "Hand-Held-Calculator Programs for the Field Forester," General Technical Report RM-76-FR24, by Wayne D. Sheppard.

# Managing spruce-fir

Engelmann spruce-subalpine fir forests are not only the largest and most productive timber resource in the central Rocky Mountains, but they provide habitat for a wide variety of wildlife, forage for livestock, recreational opportunities, scenic beauty, and the majority of water for this region.

Researchers at the Rocky Mountain Station have used RMYLD, a field and computer simulation program, to predict the potential production of this forest type in the central Rockies under various combinations of stand density, site quality, rotation age and thinning schedule. These estimates are useful to land managers to project future development of stands managed in different ways for various uses.

If you would like a copy of the paper describing the use of this simulation program, write the Rocky Mountain Station and ask for "Management of Spruce-Fir in Even-Aged Stands in the Central Rocky Mountains," Research Paper RM-217-FR24, by Robert R. Alexander and Carleton B. Edminster.

# Ponderosa pine growth analyzed

The first results from studies of the effects of thinning, spacing, and brush competition on planted ponderosa pine in northern California are presented in two new reports by Research Forester William W. Oliver of the Pacific Southwest Station.

In "Growth of Planted Ponderosa Pine Thinned to Different Stocking Levels in Northern California," Oliver describes the effects of thinning pole-sized ponderosa pine to growing stock levels of 40, 70, 100, 130, and 160 square feet of basal area per acre. His study site, a 20-year-old plantation on the west slope of the northern Sierra Nevada, is comparable to other highly productive sites in the west-side Sierra Nevada and the Cascade Range.

Oliver monitored the plots for five years after thinning, measuring growth in diameter, basal area, height, volume, and crown width. He reports, "Surprisingly, only trees in plots that were heavily thinned to 40 square feet of basal area per acre grew faster in diameter after thinning than before thinning. At all of the higher stand densities, the rate of diameter growth was substantially less after thinning."

He explains that this response to thinning was probably influenced by the initial spacing of the stand. "Before thinning, the trees were uniformly spaced (at 6 by 8 feet) and were healthy and vigorous. Their periodic annual growth—in both diameter and volume—was at its peak. After thinning, diameter growth of trees at all the higher growing stock levels continued the decline that normally follows the culmination of periodic annual growth."

Oliver contends that even though thinning contributed to a potential loss in stemwood volume on a per acre basis, thinning should pay off in the long run, through the shortened period of time needed for trees to reach sawlog size and through the improved health of the stand. He contends that the thinned stand "could be ready for commercial harvest 15 years sooner than an unthinned stand. The growth of trees

in the plots that were thinned to 160 square feet of basal area per acre may seem adequate now, but thinning to a growing stock level of 100 would bring the plantation to merchantable size 15 years sooner—at age 35 for growing stock level 100 against age 50 for growing stock level 160." In regard to the health of the stand, Oliver says, "An unthinned stand, similar in productivity to the one I studied, is likely to have a density of 300 square feet of basal area per acre at age 50. Growth losses, including mortality from intertree competition, and possibly from bark beetles, could be substantial. In contrast, stands thinned to growing stock level 100 could reach 200 square feet of basal area per acre at age 35 years. This density is sufficient to support a commercial thinning, yet is probably not dense enough to jeopardize the health of the stand." Further details are in his report, Research Paper PSW-147.

In a second study of ponderosa pine in northern California, Oliver found that spacing and brush competition "strongly influence stem diameter at breast height, as well as crown width, live crown ratio, and average branch diameter 12 years after planting." His results came from tests of five different spacings, ranging from 6 by 6 feet to 18 by 18 feet, used on study plots located at 2,650 feet elevation on the west side of the Sierra Nevada. At the outset of the study, ponderosa pine seedlings were planted in brush-free plots. During the next 12 years, Oliver monitored tree growth on study plots where brush was allowed to reinvade, and on sites where brush was killed by hand or with an herbicide.

On several plots, Oliver found that competition from such brush species as whiteleaf or Indian manzanita, deerbrush, and Sierra gooseberry, or from the sprouts of California black oak or tanoak, resulted in a loss equivalent to 3 years growth in tree diameter. Within each spacing, trees in the brushy plots tended to be smaller and more variable in size than trees in the brush-free plots. Competition between trees in brush-free plots began during the 8th year for trees spaced at 6 by 6 feet, and during the 10th year for trees spaced 9 by 9 feet. By the 12th year, however, intertree competition had not yet begun for trees spaced 12 feet apart, or wider.

More information on the study is in Research Note PSW-341, "Early Response of Ponderosa Pine to Spacing and Brush: Observations on a 12-year-old Plantation." Copies of both of Oliver's reports are available from the Pacific Southwest Station.

# Timber bidding methods examined

Does selling federal timber by sealed bids in the Western United States bring more revenue to the federal purse than selling by oral bidding? Apparently it did during 1977 when sealed bidding was the usual sale method. In a new report from the Pacific Northwest Station, Economist Richard Haynes says that, in general, sealed bidding increased competition in the regions studied. The increase was substantial in the prime forests west of the Cascades in Oregon and Washington, where sealed bidding brought in an extra $54.2 million on sales of $653.8 million. In Montana and Idaho sealed bidding increased revenue by $6.2 million on sales of $50.3 million.

Hayes arrived at this conclusion after measuring the amount by which sealed and oral bids exceeded the minimum price the Forest Service set on timber in three areas: Idaho and Montana, Oregon and Washington, and California. He compared sales for fiscal years 1975 and 1976 with calendar year 1977, when sealed bidding was common.

The report brings some hard facts to the longstanding controversy about the respective advantage of sealed and oral bidding for federal timber. One aspect of the controversy that has not been studied previously is the effect of outside bidders. Haynes found that outside bidding had been going on before the adoption of sealed bidding. He concluded that other factors, such as a decline in timber availability and concern about maintaining control of particular markets provided a better explanation of outside bidding than bidding method.

The controversy about bidding method is currently dormant because competition is setting new records for stumpage prices and because the law making sealed bidding the primary sales method was changed by Congress in 1978 to restore the bidding methods traditional for each area.

The report also contains an examination of the Small Business Set-Aside program. Haynes found that in some areas the program had led to lower prices for those firms winning set-aside sales.

Copies of "Competiton for National Forest Timber in the Northern, Pacific Southwest, and Pacific Northwest Regions," Research Paper PNW-266, by Richard W. Haynes, are available from the Pacific Northwest Station.

## Stream dynamics for land managers

Streams are important components in any ecosystem, and land managers need to understand the general concepts of stream behavior to learn how management actions affect these waterways.

A new report is out that presents a general outline of water flow, sediment transport, and other major processes of stream dynamics. It shows how the complexity of stream behavior forces the land manager to consider the individual components of each case. The report emphasizes that stream restraining measures must be applied with great caution so that treatment of one critical location will not simply lead to the formation of another problem, or that the side effects of treatment will not be more detrimental to stream improvement than no treatment at all.

The report covers: the basic fluvial process, equilibrium condition and adjustment processes, monitoring stream behavior, and a listing of literature citations on stream dynamics.

For your copy, write the Rocky Mountain Station and request "Stream dynamics: An Overview for Land Managers," General Technical Report RM-72-FR24, by Burchard H. Heede.

## Brushland management symposium planned

A symposium on management of brushlands in southern California, the Southwestern U.S., and other regions of the world that have a Mediterranean-type climate, will be held June 22-26, 1981, in San Diego, California. The conference is designed for researchers, land managers, and others interested in current brushland management practices and recent advances in brushland management research. Topics will include the effects of brushland management on vegetation, wildlife, soils, and hydrology; the use of prescribed fire as a management tool; and new ways to make better use of brushlands.

The conference, which is titled "Dynamics and Management of Mediterranean-type Ecosystems: An International Symposium," is sponsored by the Pacific Southwest Forest and Range Experiment Station and by San Diego State University. Co-sponsors include the Sierra Club, National Park Service, and several other State, Federal, and international organizations.

More information is available by writing to: Chairman, Dynamics and Management of Mediterranean-type Ecosystems: An International Symposium, Pacific Southwest Forest and Range Experiment Station, 4955 Canyon Crest Drive, Riverside, California 92507 U.S.A.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